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The effect of hydrated lime addition in improving the moisture resistance of hot mix asphalt (HMA)

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Abstract. It is desirable to have pavement surfaces that last until its designed life. Ravelling, rutting, and potholes are one the pavement failures that are commonly found and those failures are related to the intrusion of moisture onto the asphaltic mixture. This research aims to study the usage of hydrated lime as an additive to improve the moisture susceptibility of the asphaltic mixture. There were two different natural aggregates used in this research project and the prepared specimens were tested by Marshall, Cantabro Loss, and Indirect Tensile Strength tests. From the research results, it was found that hydrated lime was effective in not only improving the moisture susceptibility of the asphaltic mixture, but also increasing the stability and making the asphalt specimens denser. It was also found that it is critical to choose the suitable aggregate to be used in the asphaltic mixture as it can significantly affect the quality of the asphalt specimens.

Keywords: Hydrated Lime, Aggregate, Cantabro Loss, Marshall Test, Indirect Tensile Strength Test

1. Introduction

Having pavement distresses at early stage is one of the main issues for road engineers. In major cities in Indonesia, it is very common to find moisture-induced pavement distresses in flexible pavement with asphaltic mixture as the wearing surface, such as ravelling, rutting, and potholes [1]. To overcome the issues related to moisture in asphaltic mixture, anti-stripping agent is normally used, such as Elvaloy® [2], hydrated lime [3]–[5], and Zycosoil [6], [7]. There are a number of research projects that have been conducted to study the effect of water or moisture in asphaltic mixture [8]–[10]. There are a number of factors that affect the susceptibility of asphaltic surfaces, such as the aggregates properties (minerals, source of aggregate, angularity, dust, and moisture content), the asphalt binder properties (stiffness, chemical composition, and refining process) [1], [11]. This research project aims to analyse the effect of hydrated lime in improving the moisture resistance of asphaltic mixtures or hot mix asphalt (HMA) that were constructed by using two different natural local aggregates.



2. Experimental design

2.1. Materials

There were two aggregates used in this research, which were sourced from different quarries. In this paper, the aggregate will be referred as “Aggregate A” and “Aggregate B”. Both aggregates were sieved into four different sizes as listed in Table 1. Some preliminary tests were also conducted to check the suitability of the aggregates to be used in the asphalt mixture, as listed in Table 2 and Table 3.

From the test results obtained, it can be seen that both aggregates met almost all of the requirements stated in the *Standar Nasional Indonesia* (SNI). For both Aggregate A and Aggregate B, the bulk specific gravity was slightly lower than and the absorption was slightly higher than the requirements. However, the aggregates were still used in this research project as those aggregates have been used in a number of road construction projects.

Table 1. Aggregates grading

Aggregate	Passed Sieve No.	Retained by Sieve No.
I	¾” (19.1 mm)	3/8” (9.6 mm)
II	3/8” (9.6 mm)	#8 (2.4 mm)
III	#8 (2.4 mm)	#16 (1.2 mm)
IV	#16 (1.2 mm)	#200 (0.075 mm)

Table 2. Test results for Aggregate A

Tests	Standards	Results				Requirements
		I	II	III	IV	
Bulk Specific Gravity		2.45	2.41	2.40	2.32	
SSD Specific Gravity	SNI 1969:2008 and	2.52	2.50	2.56	2.62	≥ 2,5 gr/cc
Apparent Specific Gravity	SNI 1970:2008	2.63	2.65	2.52	2.53	
Absorption (%)		2.80	3.75	1.87	3.61	≤ 3
Los Angeles Abrasion (%)	SNI 2417:2008		21%			≤ 40

Table 3. Test results for Aggregate B

Tests	Standards	Results				Requirements
		I	II	III	IV	
Bulk Specific Gravity		2.33	2.37	2.42	2.42	
SSD Specific Gravity	SNI 1969:2008 and SNI	2.45	2.45	2.96	3.07	≥ 2,5 gr/cc
Apparent Specific Gravity	1970:2008	2.64	2.64	2.80	2.88	
Absorption (%)		5.04	4.26	5.61	6.56	≤ 3
Los Angeles Abrasion (%)	SNI 2417:2008			11%		≤ 40

Moreover, a commercially available asphalt with 60/70 penetration was used as a binder in this research project. Like the aggregates, the binder was also tested for its suitability before being used in the asphalt mixture and the results are listed in Table 4. The percentage of binder used was different for both aggregates. By using the Marshall tests, it was determined that the percentage of binder used for Aggregate A and Aggregate B were 6% and 5.5%, respectively.

Table 4. Binder Test Results

Tests	Standards	Result	Requirements
Penetration Test at 25°C (0.1 mm)	SNI 06-2456-1991	62	60-70
Specific Gravity (gr/cc)	SNI 2434-2011	1.167	≥ 1.0
Ductility at 25°C (cm)	SNI 2441-2011	111	≥ 100
Softening Point Test (°C)	SNI 2432-2011	55	≥ 48
Flash Point Test (°C)	SNI 06-2433-1991	364	≥ 232
Fire Point Test (°C)	SNI 06-2433-1991	336	≥ 288

In this research project, there was an additive added, which was the hydrated lime. It is one of the common natural additives that can be used to improve the performance of asphaltic mixture [3]–[5]. There are a number of advantages in using this additive, including stripping reduction, asphalt stiffening improvement, and it can improve the resistance of HMA to fracture growth [12]. Also, a study in [12] shows that there is a significant saving in using hydrated lime in asphaltic mixture and an improvement in expected pavement age. The dosage for the hydrated lime added for this study was 1%, 1.5%, and 2%.

2.2. Laboratory Tests

There were three tests that were conducted for the asphalt mixture, which are the Marshall, Cantabro Loss, and Indirect Tensile Strength (ITS). A detailed procedure for these tests can be found in [13]. Each test was repeated three times to ensure that the data obtained is statistically significant.

3. Results and Discussion

3.1. Marshall Test Results

Table 5 and Table 6 show the results for Marshall tests conducted for Aggregate A and Aggregate B, respectively. There were a number of parameters analysed, including stability, flow, Void in Mixture (VIM), Void Filled with Asphalt (VFA), Void in Mineral Aggregate (VMA), and density. From Table 5, it can be seen that the samples constructed with Aggregate A only (without additive) satisfied all the requirements, except for the density values. This could be caused by the sample preparation method where a manual compactor was used, and hence, it was possible that the sample was not compacted as good as if gyratory compactor or another automatic compactor was used.

Unlike samples constructed with Aggregate A, the samples constructed with Aggregate B only (without additive) had a low stability value and less than the value required. The VIM, VFA, and density parameters also did not meet the requirements. The lower density values could be caused by the same reason as the samples constructed with Aggregate A. However, the values of VIM and VFA parameters did not meet the requirements could be caused by another factor, such as the shape of the aggregates that did not allow the aggregates to have good interlocking with one another.

Table 5 and Table 6 also show the Marshall test results conducted for samples mixed with Aggregate A and Aggregate B, respectively, and different percentages of hydrated lime added. It can be seen for both sample variations, the higher the percentage of hydrated lime, the higher the stability values would be. For the samples mixed with Aggregate B, the addition of hydrated lime at 1.5% and 2% was able to help the samples to reach the minimum stability value. For the samples constructed with Aggregate A, other than stability parameter, the addition of hydrated lime did not change the other parameters significantly. However, for the samples constructed with Aggregate B, the addition

of hydrated lime could make the VIM lower, VFA higher, and VMA lower by quite significantly, which showed that the samples constructed became denser, and hence, stronger.

Table 5. Marshall test results for samples with Aggregate A

Parameters	Unit	% Hydrated Lime				Requirements
		0	1.0	1.5	2.0	
Stability	kg	986.46	1026.44	1085.82	1091.41	> 800 kg
Flow	mm	2.83	2.8	2.8	2.6	2-4 mm
VIM	%	4.64	4.58	4.49	4.40	3-5 %
VFA	%	76.84	77.06	77.75	77.7	> 65%
VMA	%	20.03	19.98	20.16	19.71	> 15%
Density	gr/cm ³	2.02	2.03	2.02	2.03	≥ 2,2

Table 6. Marshall test results for samples with Aggregate B

Parameters	Unit	% Hydrated Lime				Requirements
		0	1.0	1.5	2.0	
Stability	kg	620.71	781.42	843.95	923.20	> 800 kg
Flow	mm	3.17	2.93	2.80	2.70	2-4 mm
VIM	%	11.36	6.05	5.98	5.74	3-5 %
VFA	%	44.24	70.94	63.61	64.67	> 65%
VMA	%	20.37	20.80	16.45	16.23	> 15%
Density	gr/cm ³	2.00	2.01	2.01	2.01	≥ 2,2

3.2. Cantabro Loss Test Results

Figure 1 shows the Cantabro Loss test results for both samples constructed with Aggregate A and Aggregate B. The x-axis shows the percentage of hydrated lime used and the y-axis shows the percentage of Cantabro Abrasion Loss (CAL). CAL represents the percentage of materials lost during abrasion, and hence, the lower the percentage of CAL, the stronger the asphaltic mixture is.

From Figure 1, it can be seen that the specimens constructed with Aggregate A had lower CAL values compared to the specimens constructed with Aggregate B. This shows that the specimens constructed with Aggregate A were stronger against abrasion at moist condition. This could be caused by the fact the Aggregate B had higher water absorption value, as listed in Table 3. The procedure in Cantabro Loss test involved the asphalt specimen being immersed in water for a period of time. During this procedure, it seemed that the specimens constructed with Aggregate B absorbed more water, which results in “weaker” aggregates.

Moreover, it can be seen that the addition of hydrated lime can improve the resistance to water for both specimen variation. The higher the percentage of hydrated lime added, the lower the CAL values, which means that the specimens were becoming more resistant.

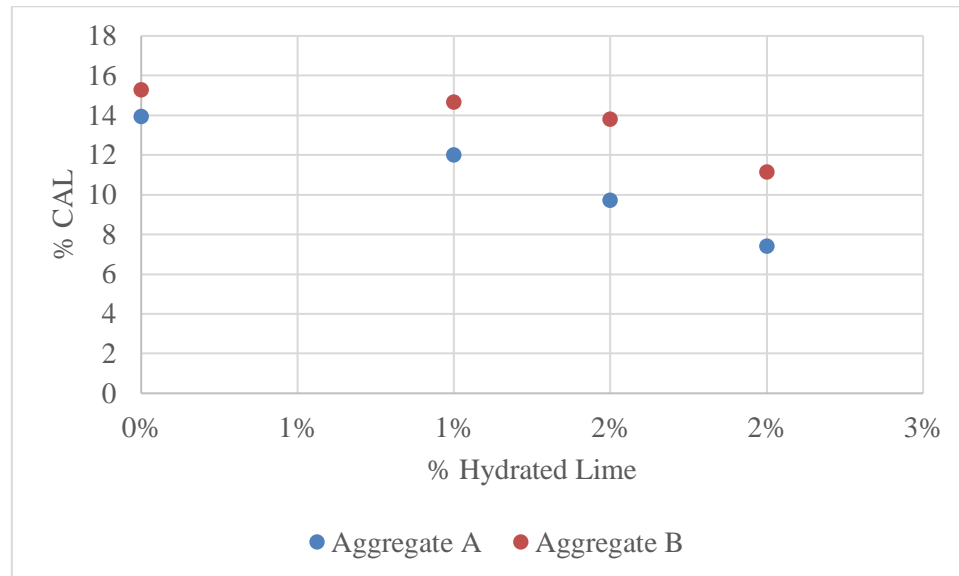


Figure 1. Cantabro Loss test results

3.3. ITS Test Results

Figure 2 shows the comparison between the ITS values at saturated and dry condition for both samples constructed with Aggregate A and Aggregate B. The ITS value for dry condition is written as “ITS-Dry” and ITS value for saturated condition is written as “ITS-Sat”. It can be seen that the ITS-Sat values for all sample variations were lower than the ITS-Dry, which was expected. The strength of the asphalt specimens at wet or saturated condition would be lower than in dry condition. The specimens constructed with Aggregate A had higher ITS-Dry and ITS-Sat values for all samples compared than the specimens constructed with Aggregate B. This could be caused by the fact that Aggregate B has higher water absorption value, as seen in Table 2. Similar to Cantabro Loss test, the ITS test procedure also involves immersing the asphalt specimens in water for a period of time (24 hours for ITS test).

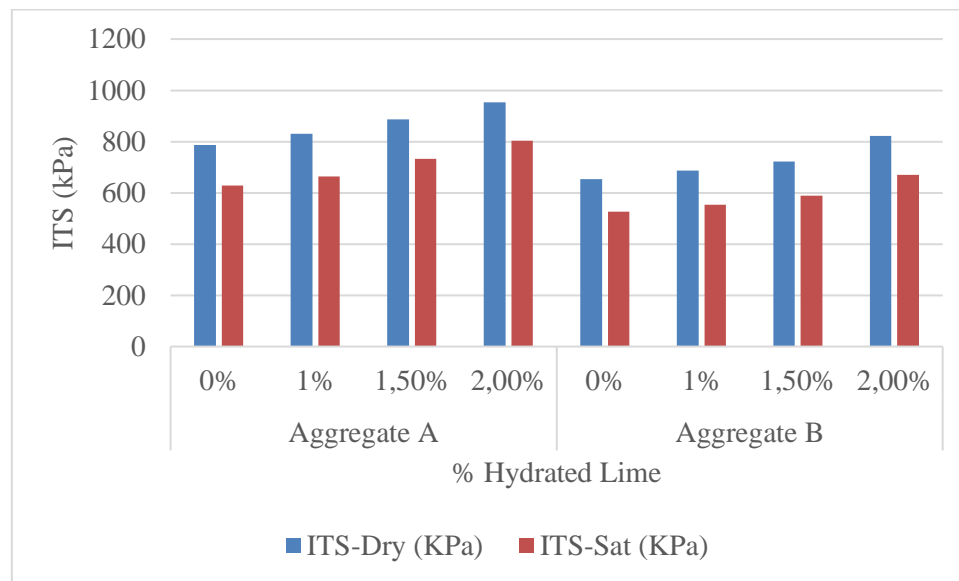


Figure 2. ITS test results

Figure 3 shows the Tensile Strength Ratio (TSR) values for both samples prepared with Aggregate A and Aggregate B, which is the ratio between the ITS-Sat to ITS-Dry. The lower the TSR means that the difference between ITS-Sat and ITS-Dry becomes larger, which suggests that the asphalt specimens at saturated or wet condition lost more strength. From Figure 3, it can be seen that for asphalt specimens prepared with Aggregate A had low TSR values when there was no additive added, but as the percentage of hydrated lime increases, the TSR values also increases, which suggests that the hydrated lime was effective in improving the moisture resistance of the specimens. For the asphalt specimens prepared with Aggregate B, the TSR value for the control sample was slightly higher than the control sample with Aggregate A. The addition of hydrated lime these specimens helped in improving the resistance to moisture for the samples prepared with Aggregate B, but it did not change as much.

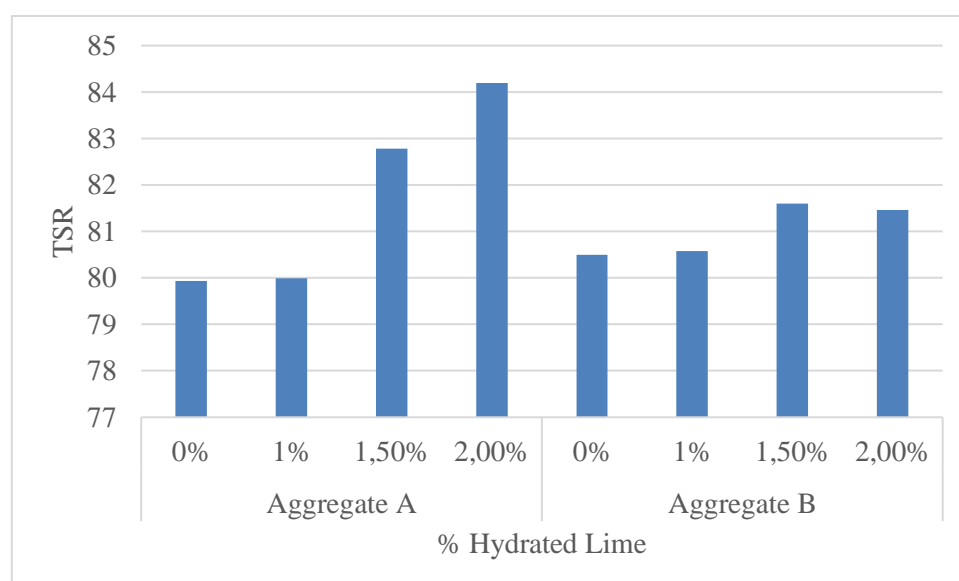


Figure 3. Comparison of TSR values

4. Conclusions

Potholes and stripping are one of the most commonly occurring distresses in flexible pavement with asphaltic mixture as its wearing course. These failures are related to the intrusion of moisture onto the mixture. In order to solve this issue, many engineers add additives to the asphaltic mixture to improve the moisture resistance of the asphaltic mixture. In this research project, the usage of a natural additive, namely the hydrated lime, was mixed onto asphaltic mixtures that were constructed by using two different natural local aggregates. There were three tests conducted in this research project, which are the Marshall test, which was used to determine the strength of the asphalt mixture, the Cantabro Loss and the ITS tests, which were used to analyse the moisture susceptibility of the HMA.

From the research results, it can be seen that asphalt specimens that were constructed by using Aggregate A had a higher stability than the specimens that were constructed by using Aggregate B. Some parameters of the specimens that were mixed with Aggregate B, such as stability, VIM, and VMA, did not meet the required value. However, the addition of hydrated lime onto those mixtures was able to improve the stability and the other Marshall parameters of both mixtures. With addition of 1.5% and 2% of hydrated lime, the stability, VIM, and VMA parameters of the HMA specimens that were constructed by using Aggregate A could achieve the minimum desired values.

Based on the Cantabro Loss and ITS tests, it can be concluded that the HMA specimens that were prepared by using Aggregate A had a higher resistance to moisture than the other specimens. The addition of hydrated lime was deemed to be successful in improving the moisture susceptibility of the asphalt samples for both mixtures. It can be seen by the lower CAL values and the higher TSR values as the percentage of hydrated lime increases.

To sum up, it can be understood from this study that the natural additive, hydrated lime, is effective in improving the quality of the asphaltic mixture and the aggregate used in asphaltic mixture is critical in determining the quality or the strength of the asphaltic mixture.

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